PROVIDING ENVIRONMENTAL REPRESENTATION AND ENVIRONMENTAL EFFECTS IN THE DMSO HLA: EXPERIENCES FROM ONE PROTOFEDERATION*

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KEYWORDS
HLA, Environmental Representation, Synthetic Environments

ABSTRACT

Argonne National Laboratory participated in the HLA prototyping effort as a member of the Joint Training Federation prototype (JTFp) team. Within the JTFp, Argonne provided the common environmental representation and functionality for the federation utilizing the Dynamic Environmental Effects Model (DEEM). In addition to acting as a source of environmental representation and functionality to the JTFp, DEEM was also used as a Scenario Monitor for the overall simulation to provide a "commander's eyeview" of the simulated engagement.

In this paper, we discuss the procedures used to arrive at a common environmental representation for the federation and to summarize the environmental functionality that was provided. In addition, we present results detailing any performance implications related to providing environmental representation and functionality in future HLA federations.

1.0 INTRODUCTION

The Joint Training Federation Prototype (JTFp) is one of a group of prototype efforts that have been created to provide a test of the Defense Modeling and Simulation Office (DMSO) High Level Architecture (HLA). As with all of the prototype efforts, the goal is to provide a robust test of the HLA and its usefulness for the DoD Modeling and Simulation (M&S) Community.

The Joint Training Federation has been created to address HLA issues from the perspective of the training community. The environment is one factor that must be addressed in military training. In order to represent the environment in the JTFp, Argonne's Dynamic Environmental Effects Model (DEEM) has been included as one of the JTFp federates.

2. OVERVIEW OF THE JOINT TRAINING FEDERATION PROTOTYPE

The Joint Training Federation was created to examine the implications of the HLA on a training community. In order to achieve this goal, a scenario was created to simulate the kinds of conditions facing the training community.

The JTFp scenario covers a 24 hour conflict occurring in the fictional country of "Protofederatia" and includes four vignettes that describe aspects of the conflict and involve

*Work supported under a military interdepartmental purchase request from the U.S. Department of Defense, Joint Chiefs/J-8, through U.S. Department of Energy contract W-31-109-Eng-38.

different types of military response. The four vignettes are: a Marine Amphibious Landing, Theater Ballistic Missile Defense and Response, Urban Harbor Protection, and Attack Operation.

Figure 1 gives a schematic representation of the JTFp. Three programs, the National Air and Space [Warfare] Model (NASM), the Naval Simulation System (NSS), and War-Sim 2000 (represented by the Eagle model) represent warfighting federates from the land, air, and sea communities, respectively. The JSIMS Joint Program Office (JPO) is providing a Joint Task Force Headquarters model as a source of Command and Control contributions to the federation. The Dynamic Environmental Effects Model (DEEM) will play two roles in the JTFp effort. First, it will act as an Environmental Server and provide environmental representation and functionality to the federation. Second, DEEM will act as a Scenario Monitor to provide a global, "commander's view" of the simulation. This will be accomplished by using the DEEM GeoViewer, an object-oriented geographical information system. Finally, there will be a set of federation-level services that will be provided to control the federation as well as to do performance testing of the RTI.

Figure 2 shows a schematic representation of the object hierarchy being used by the JTFp Federation Object Model (FOM). Figure 2 also identifies those objects that DEEM will be responsible for publishing in the federation.

3.0 ENVIRONMENTAL FEDERATE DEVELOPMENT PROCESS

It is well understood that the environment has an impact on military operations. However, the level of environmental representation and functionality among DoD models varies greatly. Among the JTFp warfighting federates, there is a great variation in the level of environmental representation and functionality.

One of the purposes of including DEEM in the JTFp was to study how to provide a common environmental representation across the federation. In order to accomplish this, it was necessary to determine the environmental objects, data, and functionality requirements of the federates and to express them in a manner that was consistent throughout the federation. This was accomplished using an environmental object development process consistent with the HLA Federation Object Model development process.

3.1 Identifying the "Real World" Environmental Interactions

A review of the JTFp vignettes indicated that three environmental objects would be required to address JTFp environmental needs: Surface Cover, Atmosphere, and Open Water. The Surface Cover object addresses all terrain interactions and the Open Water object is used to address oceanic interactions.

The environmental interactions that would be required were assessed by determining what kind of "real world" environmental interactions existed in the vignettes. Table 1 lists the interactions that have been identified for one of the four JTFp vignettes in terms of the primary Environment object involved and if the interaction is going to be considered in the JTFp. The decision to include an interaction has been based on whether or not the JTFp federates are able to model the noted interaction and is not a determination of the "importance" of the interaction. Upon review of the information in Table 1 and those constructed for the other three vignettes, it was concluded that the interactions that could be supported within the JTFp consisted of providing information about atmospheric conditions at user specified positions, visibility, sea state conditions, and information related to surface cover conditions.

3.2 Development of the JTFp Environmental Objects

The JTF "environment" consists of a superclass object, the Environment, and three "leaf node" objects: Atmosphere, Surface Cover, and Open Water. The Environment Object contains only one attribute, the "Area of Interest" attribute, that defines the bounding box of the area being studied. For the purposes of this effort, Korea was acting as the surrogate for "Protofederation."

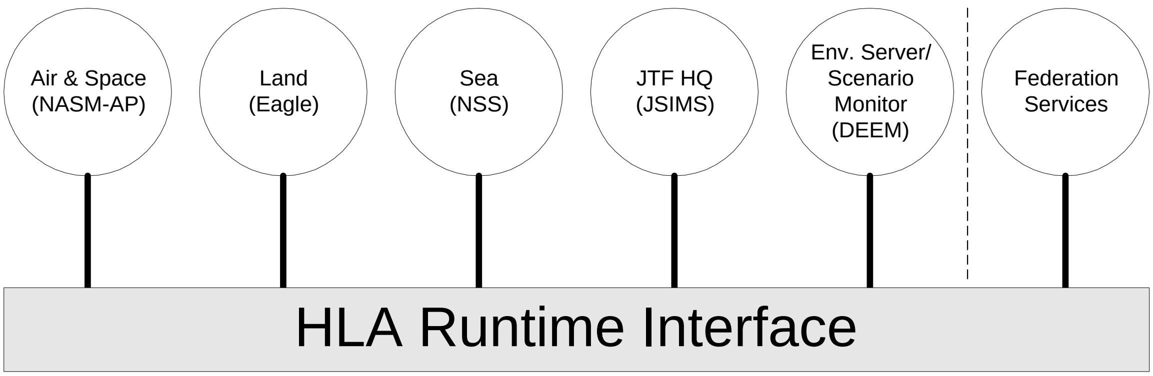

Figure 1. Schematic Representation of the HLA Joint Training Federation Prototype.

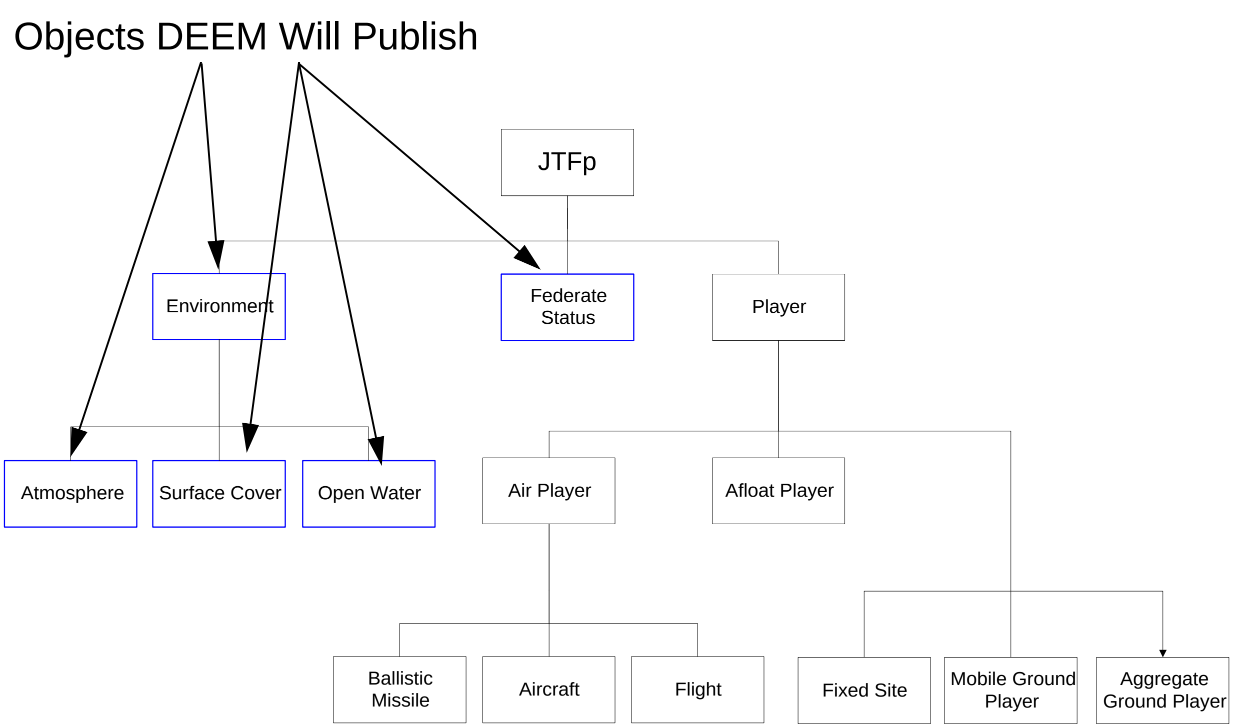

Figure 2 The Object Hierarchy in the JTFp and the Objects DEEM Will Publish.

Table 1. "Real World" Environmental Interactions and Those Being Considered in the JTFp Theater Ballistic Missile Defense and Response Vignette

"Real World" Environmental Interactions/Requirements	Considered in JTFp
Atmosphere Object	
1. Surface weather conditions for launching and recovery of aircraft from carrier and airbase	Yes
2. Weather conditions at flight levels for:	
a) Early Warning assets	No
b) Tankers	No
c) Combat Air Patrol	Yes
3. Weather forecasts for ATO generation	No
4. Cloud and obscurant conditions for line-of-sight estimates	Yes
5. Need atmospheric state data for sensor performance	Yes
6. Propagation Impacts on Communications	No
7. Atmospheric drag on satellite assets	No
8. Boundary layer winds for:	
a) Plume transport from smoke sources	Yes
b) NBC threat assessment	No
Water Object	
1. Need 2-D surface extent for force placement:	Yes
2. Bathymetry	No
3. Water properties (*e.g.*, salinity, thermal structure, etc.)	No
4. Surface sea state conditions for carrier search and rescue	No
Land Object	
1. Positions and descriptions of artifacts (*e.g.*, buildings, harbor facilities, transportation networks, ...)	No
2. Know relative position of all military assets on the ground	Yes
3. Terrain masking for line-of-sight estimates	Yes
4. Calculation of vehicle speeds (also need weather data)	Yes
5. Line-of-sight impacts on communications	No
6. Dust generation from vehicle operations	No
7. Dynamic terrain modification (*e.g.* craters) from battle	No
Other Environmental Needs	
1. Need time of sunrise	No
2. Position of sun	No

Tables 2, 3, and 4 provide descriptions of the "leaf node" JTFp environmental objects. The Tables include the attributes, units, the attribute types, if it is static or will be updated, and the conditions under which it can be updated. During the HLA testing, DEEM will not transfer ownership of any of the environmental objects since no other JTFp federate has the ability to take on ownership responsibility of the environmental objects.

3.2.1 Atmosphere Object

Table 2 describes the JTFp Atmosphere Object. The creation of the Atmosphere Object was based, primarily, on the needs of NASM and is based on standard Air Force weather products. For the basic JTFp HLA testing, the Atmosphere Object was assumed to be representative of a homogeneously uniform atmosphere. As such, the object was instantiated at an effective point in the JTFp area of interest that was described by the "atmos_object_extent" attribute. The "real" atmosphere is, of course, not horizontally homogeneous and a set of additional tests have been planned to test the impacts of instantiating the Atmosphere Object as a fully 3-D gridded object.

3.2.2 Surface Cover Object

The JTFp Surface Cover Object, described in Table 3, will be used primarily by Eagle, to provide information about surface conditions for use in ground operations.

As noted in Table 3, the Surface Cover will not be updated after the initial instantiation. In a simulation involving dynamic terrain effects, the Surface Cover Object would be updated whenever the terrain underwent modification. The changes to the Surface Cover object could result from natural environmental effects, such as hydrologic processes; or environmental effects with a human hand involved, such as the building of berms.

3.2.3 Open Water Object

The Open Water object is meant to represent all oceanic areas in the JTFp study area. Due to the limited interactions involving the oceanic areas, the Open Water is limited in extent. Table 4 describes the JTFp Open Water object. The Open Water object will be instantiated at a single point and will be updated on a periodic basis at the same basic rate as the Atmosphere object.

Table 2 Description of the JTFp Atmosphere Object

Attribute	Units	Type	Update Type	Update Condition
atmos_object-extent	deg, deg, m	Bounding box of latitude and longitude points describing the atmospheric area of extent	Static	-
ceiling	m	Float	Periodic	Fixed Time Rate
surface_temperature	K	Float	Periodic	Fixed Time Rate
surface_pressure	mb	Float	Periodic	Fixed Time Rate
visibility	km	Float	Periodic	Fixed Time Rate
relative_humidity	%	Float	Periodic	Fixed Time Rate
surface_wind_speed	m/s	Float	Periodic	Fixed Time Rate
surface_wind_direction	degrees	Float	Periodic	Fixed Time Rate
total_cloud_cover	%	Float	Periodic	Fixed Time Rate
cloud _type*	-	String (Cumulus, Cumulonimbus, Stratus, Nimbostratus, Altostratus, Cirrus)	Periodic	Fixed Time Rate
cloud _amount*	-	Float	Periodic	Fixed Time Rate
cloud_height*	m	Float	Periodic	Fixed Time Rate
precipitation_amount	mm	Float	Periodic	Fixed Time Rate
natural_obscurants	-	String (Fog, Rain, Dust, Snow, Haze)	Periodic	Fixed Time Rate
artificial_obscurants	-	String (None, Smoke)	Conditional	Updated as the battle progresses.

*Up to Three Clouds (*e.g.* Low, Middle, High) Will Be Accounted For.

Table 3 Description of the JTFp Surface Cover Object

Attribute	Units	Type	Update Type	Update Condition
surface_object_extent	deg, deg	Locus of Points Describing the Surface Cover Object	Static	-
cover_type	-	String (Bare, Developed, Wetland, Grassland, Forest, Cane, Plantation, Cropland, Scrub, Vineyard, Miscellaneous Vegetation, Water)	Static	-
vegetation_density	%	Float	Static	-

Table 4 Description of the JTFp Open Water Object

Attribute	Units	Type	Update Type	Update Condition
water_object_extent	deg, deg	Latitude and Longitude Points Where Data are Provided	Static	-
state_of_sea	-	String (Calm Glassy, Calm Rippled, Smooth, Slight, Moderate, Rough, Very Rough, High, Very High)	Periodic	Fixed Time Rate
sea_surface_temperature	K	Float	Periodic	Fixed Time Rate

3.3 Objects DEEM Will Subscribe To

In addition to publishing environmental objects to the Federation, DEEM will subscribe to a number of JTFp objects. This will be done to enable DEEM to respond as the Scenario Monitor and to provide a dynamic environmental feedback.

3.4 DEEM Interactions Within the JTFp

DEEM will provide a set of environmental interactions to the JTFp. Table 5 summarizes the JTFp environmental interactions that DEEM will provide to the JTFp. The list of objects included in the Initiating Object column represents those objects that could *potentially* call the interactions.

3.4.1 Get/Return Atmospheric Conditions

The Get/Return Atmospheric Condition interactions were developed to enable a federate to obtain information about the state of the atmosphere at a given point. Table 6 lists the interaction parameters used in the Get/Return Atmospheric Condition interactions.

This interaction was designed primarily in response to the needs of NASM to obtain weather data for three different spatial regimes: over the entire area of operations (Area Weather), around an airbase (Base Weather), and at specific locations, such as over a target (Point Weather). However, the interaction can be used by any of the JTFp federates to obtain information about the atmospheric conditions anywhere in the study area. The data about Area Weather are available from the Atmosphere Object when it is published and updated. The Base and Point Weather data will be obtained from the Get Atmospheric Condition interaction.

3.4.2 Get/Return Sea State Conditions

The Get/Return Sea State interaction was developed to enable a federate to obtain data about the sea state. This interaction is required for the Marine Amphibious Landing

Vignette and would be initiated by the JTF Headquarters prior to sending out amphibious landing craft. Table 7 lists the parameters used in the Get/Return Sea State Condition interactions. In the "real" world, sea state conditions would be required over the extent of the water bodies in the area of interest. In the JTFp, the values are being given for a single, effective point.

3.4.3 Get/Return LOSVisibility

The Line-of-Sight (LOS) Visibility interaction is being used to represent all sensor issues in the JTFp. The interaction takes into account obscuring by clouds, natural obscurants at the surface (*e.g.* fog, rain, dust, snow, etc.), artificial obscurants produced from battlefield processes, and masking by terrain. Table 8 summarizes the Get/Return LOS Visibility interaction parameters.

The interaction can be called by any JTFp Player-type object that might engage in a detection/targeting effort. The position of the sensing platform and target sensed are provided as input parameters to DEEM. DEEM will then return the resulting visibility in percent and the relative humidity at the point.

DEEM will not be given the wavelength range of the assumed sensor but will return a value of visibility based on an assumed sensing in visible wavelengths. In addition, any obscuring phenomenon that is encountered is assumed to be opaque. The object that initiates the interaction will use the "Reason" flag as a way to relate the visibility value returned to that appropriate for the spectral region of the actual sensor. The relative humidity value that is also returned is a parameter that can be included in detection algorithms. In the real world, the true attenuation characteristics of the atmosphere would be calculated and used with a sensor performance model to determine if a target was detected. However, none of the JTFp warfighting federates use true sensor performance models and this approach was found to be an acceptable alternative.

Table 5 Environmental Interactions to be Provided by DEEM to the HLA JTFp.

INTERACTION	POTENTIAL INITIATING OBJECT	ENVIRONMENTAL RECEIVING OBJECT
GetAtmosphericCondition	Aircraft, Flight, Fixed Site, Mobile Ground Player, or Aggregate Ground Player	Atmosphere
ReturnAtmosphericCondition	Atmosphere	Aircraft, Flight, Fixed Site, Mobile Ground Player, or Aggregate Ground Player
GetLOSVisibility	Aircraft, Flight, Fixed Site, Mobile Ground Player, or Aggregate Ground Player	Environment
ReturnLOSVisibility	Environment	Aircraft, Flight, Fixed Site, Mobile Ground Player, or Aggregate Ground Player
Get Sea State	Afloat Player, Fixed Site, or Mobile Ground Player	Open Water
Return Sea State	Open Water	Afloat Player, Fixed Site, or Mobile Ground Player

Table 6 Description of the Get and Return Atmospheric Condition Interaction Parameters

INTERACTION	INITIATING OBJECT	RECEIVING OBJECT	INTERACTION PARAMETERS
Get Atmospheric Condition	Aircraft, Flight, Fixed Site, Mobile Ground Player, Aggregate Ground Player	Atmosphere	Time (seconds)
			Observation Latitude (deg)
			Observation Longitude (deg)
Return Atmospheric Condition	Atmosphere	Aircraft, Flight, Fixed Site, Mobile Ground Player, Aggregate Ground Player	Ceiling (m)
			Surface Temperature (K)
			Surface Pressure (mb)
			Visibility (km)
			Relative Humidity (%)
			Surface Wind Speed (m/s)
			Surface Wind Direction (deg)
			Total Cloud Cover (%)
			Cloud Type*
			Cloud Amount*
			Cloud Height* (m)
			Precipitation Amount (mm)
			Natural Obscurants
			Artificial Obscurants

*Repeated for up to three cloud layers

Table 7 Description of the Get and Return Sea State Interaction Parameters

INTERACTION	INITIATING OBJECT	RECEIVING OBJECT	INTERACTION PARAMETERS
Get Sea State	Afloat Player, Fixed Site, Mobile Ground Player	Open Water	Latitude (deg)
			Longitude (deg)
Return Sea State	Open Water	Afloat Player, Fixed Site, or Mobile Ground Player	State of Sea
			Sea Surface Temperature (K)

Table 8 Description of the Get and Return LOS Visibility Interaction Parameters.

INTERACTION	INITIATING OBJECT	RECEIVING OBJECT	INTERACTION PARAMETERS
Get LOSVisibility	Aircraft, Flight, Afloat Player, Fixed Site, Aggregate Ground Player, or Mobile Ground Player	Environment	Observation Time
			Sensor Latitude (deg)
			Sensor Longitude (deg)
			Sensor Altitude (deg)
			Target Latitude (deg)
			Target Longitude (deg)
			Target Altitude (deg)
Return LOS Visibility	Environment	Aircraft, Flight, Afloat Player, Fixed Site, Aggregate Ground Player, or Mobile Ground Player	LOS Visibility (%)
			Relative Humidity (%)
			A "Reason" Flag Describing Why Visibility is Zero (None, Masked by Terrain, Smoke, Cloud, Fog, Rain, etc.)
			Return ID Indicating Who Sent the Initial Request

4.0 SUMMARY AND IMPLICATIONS FOR FUTURE HLA FEDERATIONS

The integration of DEEM with the JTFp was completed although some changes in design concepts were required along the way. For example, the Surface Cover Object was redesigned to make it easier for the federates to use. Instead of having one large gridded object to represent the surface cover conditions over a large area, the object was redesigned to represent a large number of individual surface cover features over the same area. This design change, which was necessitated due to the legacy nature of the other federates, can lead to excessively large numbers of objects that have to be instantiated and managed. For example, if the study area was 100 km by 100 km and the surface cover objects were instantiated at a 1 km resolution, the number of surface cover objects that would be required would be 10^4. If a finer spatial resolution was required or dynamic environmental terrain effects (*e.g.* craters, tracks, etc.) were included in a simulation, the number of objects required would increase further.

Also, the original weather conditions were modified in order to insure that the NASM aircraft would be able to detect and engage targets. Later tests are planned in which the weather conditions will be stressed in order to more represent the "real world."

Working with the RTI was found to be cumbersome, although not restrictive in light of its prototype nature. It is assumed that it will be made easier to work with in future versions. The tests revealed nothing that would make the inclusion of environmental representations of effects difficult. The incorporation of spatial data filtering should make the subscription of environmental phenomenon over user-specified areas easier to accommodate. Also, the maturation of the RTI should enable future federations to be able to accommodate more complex environmental simulations.